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The Extremely Low Frequency Wave Analyzer

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Space and Environment Technology Center
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This report describes the Extremely Low Frequency Wave Analyzer flown as part of the LASSII (Low Altitude Satellite Studies of Ionospheric Irregularities) experiment aboard the CRRES (Chemical Release and Radiation Effects Satellite). This instrument measures electrostatic and electromagnetic waves in the ambient ionosphere and during the CRRES chemical releases.

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PREFACE

We wish to express our appreciation to P. Rodriguez, LASSII Principal Investigator, for the opportunity to fly the ELFWA instrument as part of the LASSII experiment. We also acknowledge the efforts of S. Imamoto, D. Katsuda, P. Lew, D. Mabry, and W. Wong in the fabrication, testing, and integration of the ELFWA instrument. This work was supported by the U. S. Air Force's Space Systems Division under Contract No. F04701-88-C-0089.

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INTRODUCTION

The Space and Environment Technology Center of The Aerospace Corporation has provided an Extremely Low Frequency Wave Analyzer (ELFWA) for the Low Altitude Satellite Study of Ionospheric Irregularities (LASSII) instrument complement on the CRRES spacecraft. The objective of the LASSII experiment is to understand the effects of naturally occurring and artificially created irregularities in the ionosphere on communication, navigation, and radar signals propagating through the ionosphere. LASSII will also determine the threat of ionospheric modification by chemical releases and high-power radio transmitters to various communication, command, control, and intelligence systems.

The ELFWA instrument measures electrostatic and electromagnetic ion waves in the ambient ionosphere and during active experiments involving chemical releases and the ionospheric heater at Arecibo, Puerto Rico. It also measures long wavelength (> 100 m) electron density irregularities. These irregularities degrade communication, navigation, and radar signals that propagate through the ionosphere.

DESCRIPTION

The ELFWA measures single-axis electric field spectra and amplitudes from 10 Hz to 250 Hz and single-axis magnetic field spectra and amplitudes from 10 Hz to 125 Hz. The instrument consists of two antennas, two preamplifiers, and two electronics boxes connected as shown in Figure 1. The electric field antenna consists of two spherical probes each 6.35 cm in diameter deployed on booms 190.5 cm long above the spacecraft as shown in Figure 2. The probes are coated with Acheson Electrodag 121 graphite semi-colloidal dispersion in an organic binder. The probes are separated by 4.5 m. Preamplifiers at the base of each boom have unity gain. The signals from the two probes are differenced in the E-field electronics package to provide a single-axis measurement of the electric field in the spin plane of the spacecraft.

The magnetic field antenna is a 50-cm diameter, 1600-turn loop of AWG36 copper wire. The antenna is deployed on a 2-m boom as shown in Figure 2. The boom consists of hinged tube assemblies constructed in two segments. It is canted slightly upward to clear the canister ejection trajectories for the chemical canisters used for the chemical release experiments. The resistance of the antenna wire is 3500 Ω and the inductance is 4.5 H. The preamp input impedance is 30 kΩ at 2200 Hz. An external load resistance is adjusted to 20 kΩ to provide 10 mV out from the antenna for a 10-nT field at 2200 Hz. At 100 Hz, a 5-nT field produces 1 mV out of the antenna. The preamplifier at the base of the boom has a gain of 100. The B-field antenna signal output frequency response is -6 dB per octave in the 125 to 12.5 Hz frequency range. The preamplifier has been frequency compensated with 6 dB per octave bass boost to produce a flat

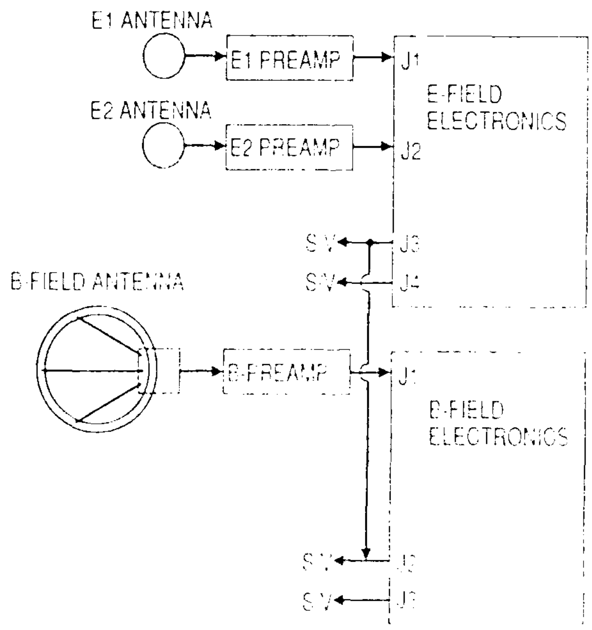

Figure 1. A block diagram of the LASSII Extremely Low Frequency Wave Analyzer.

frequency response from the antenna and preamplifier combination from 10 to 125 Hz. The single-axis magnetic field measurement is also made in the spin plane of the spacecraft.

The two electronics packages, E-field and B-field, condition the antenna signals for data storage and telemetry. Each signal is amplified into the range 0 to 5.1 V. They are then sampled at evenly spaced intervals at 250 samples per second providing a 125-Hz Nyquist frequency for the signal from each antenna. Each of the electronics packages has independent gain settings of 0, -20, and -40 dB, and two modes: linear and automatic gain control (AGC). The dynamic range is 48 dB in the linear mode and approximately 90 dB in the AGC mode at one gain setting. The experiment normally takes data in the AGC mode with the gain set at 0 dB. Then the sensitivity corresponding to 0.02 V (1 bit) output from the electronics packages is 9.9×10^{-7} V/m from the electric antenna and 0.2 pT from the magnetic antenna. The total signal in-band is also averaged and recorded each second. In a separate mode, the signal from the electric antenna is passed to the B-field electronics package as well as to the E-field electronics package as shown in Figure 1. The combined output then doubles the sampling rate of the signal from the electric antenna to 500 samples per second for a Nyquist frequency of 250 Hz.

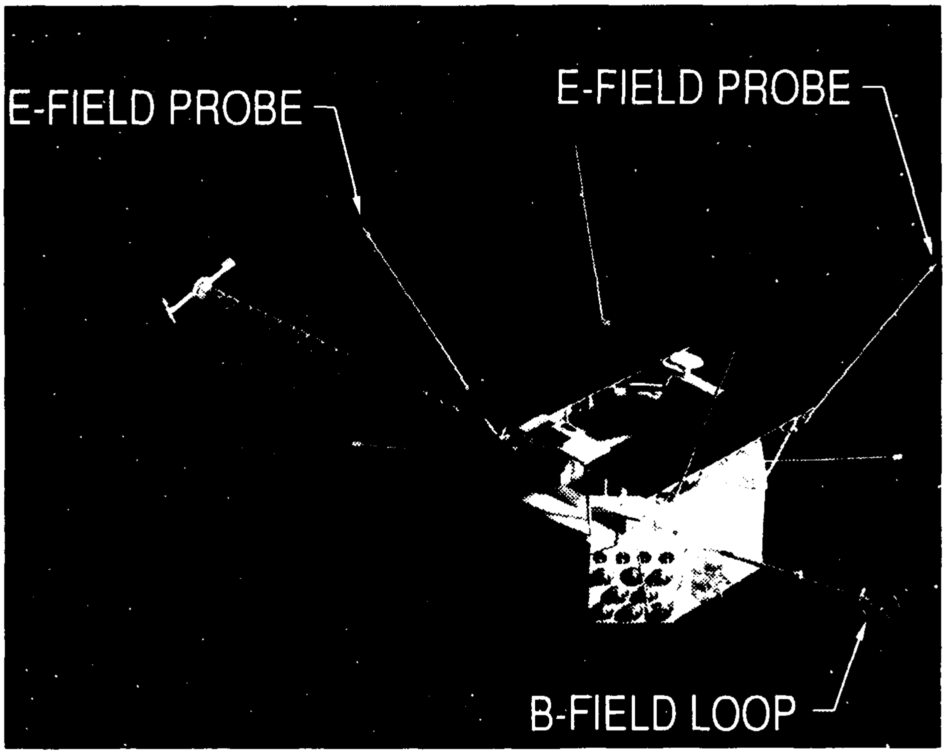

Figure 2. A picture of a model of the CRRES spacecraft identifying the E-field and B-field antennas for the ELFWA experiment.

DATA

At perigee the spectrum detected by both antennas is characterized by electromagnetic impulses across the entire frequency range from 10 Hz to 250 Hz. These impulses are most likely generated by lightning. At higher altitudes there is a hiss-like spectrum extending from 50 Hz to above the bandpass of the analyzer. This may be the lowest spectral component of plasmaspheric hiss. Figure 3. shows spectrograms of the signals from the magnetic and electric antennas during the barium chemical release from the CRRES spacecraft at 08:37:07 UT on July 19, 1991. The electromagnetic signal has spectral components across the entire band from 10 Hz to 125 Hz and lasts approximately 10 s from the time of the release.

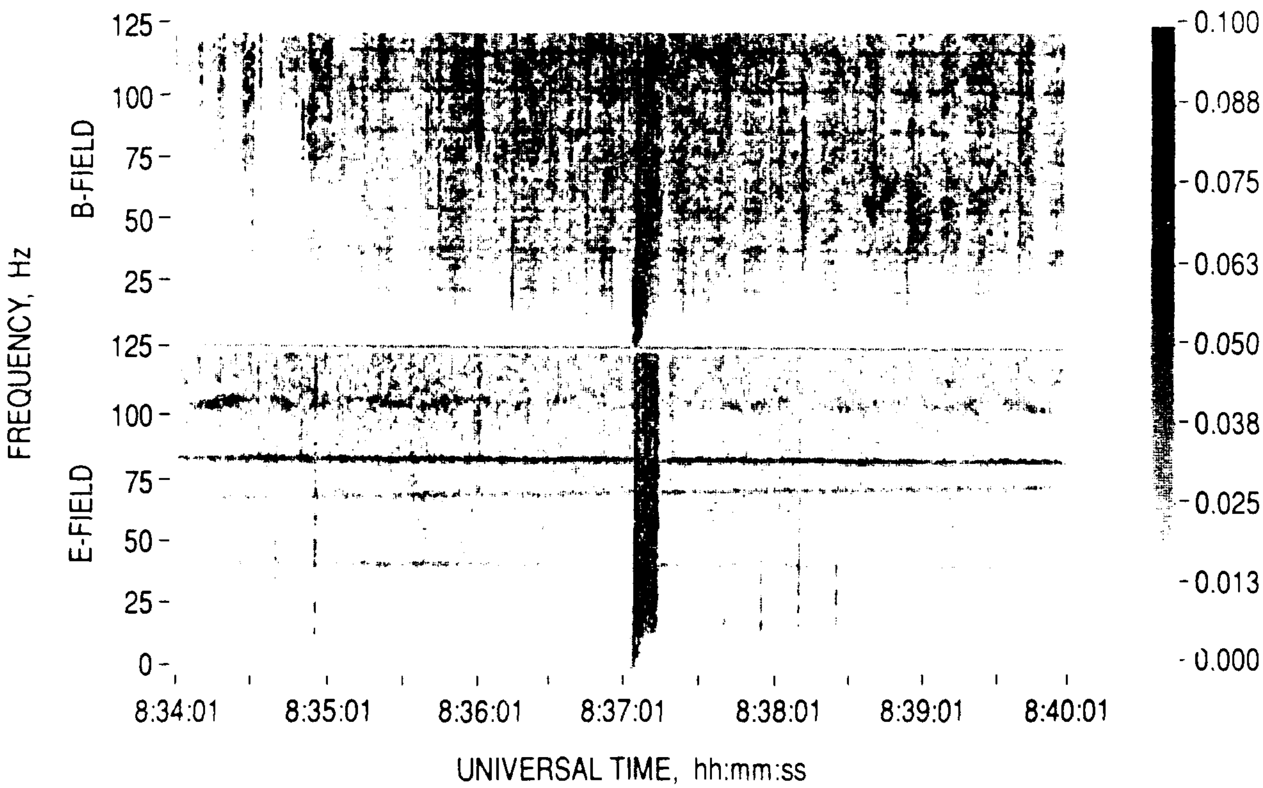

Figure 3. Spectrograms of the signals from the magnetic (top) and electric (bottom) antennas during the barium chemical release from the CRRES spacecraft at 08:37:07 UT on July 19, 1991

FLIGHT OPERATIONS

Because the LASSII telemetry format is incompatible with the format used by the wave and particle instruments, which are part of the Space Radiation Effects experiment on the same spacecraft, LASSII is duty cycled using the following scheme. When perigee is between 1730 and 0230 LT (i.e., dusk to post midnight), LASSII operates below 3000 km during every other orbit. When perigee is between 0230 and 1730 LT, LASSII operates below 1000 km every fourth orbit. During low-altitude chemical release campaigns, LASSII monitors the ionosphere for four orbits before and after each chemical release. The ELFWA instrument has been operating successfully throughout its first year on orbit.

TECHNOLOGY OPERATIONS

The Aerospace Corporation functions as an "architect-engineer" for national security programs, specializing in advanced military space systems. The Corporation's Technology Operations supports the effective and timely development and operation of national security systems through scientific research and the application of advanced technology. Vital to the success of the Corporation is the technical staff's wide-ranging expertise and its ability to stay abreast of new technological developments and program support issues associated with rapidly evolving space systems. Contributing capabilities are provided by these individual Technology Centers:

Electronics Technology Center: Microelectronics, solid-state device physics, VLSI reliability, compound semiconductors, radiation hardening, data storage technologies, infrared detector devices and testing; electro-optics, quantum electronics, solid-state lasers, optical propagation and communications; cw and pulsed chemical laser development, optical resonators, beam control, atmospheric propagation, and laser effects and countermeasures; atomic frequency standards, applied laser spectroscopy, laser chemistry, laser optoelectronics, phase conjugation and coherent imaging, solar cell physics, battery electrochemistry, battery testing and evaluation.

Mechanics and Materials Technology Center: Evaluation and characterization of new materials: metals, alloys, ceramics, polymers and their composites, and new forms of carbon; development and analysis of thin films and deposition techniques; nondestructive evaluation, component failure analysis and reliability; fracture mechanics and stress corrosion; development and evaluation of hardened components; analysis and evaluation of materials at cryogenic and elevated temperatures; launch vehicle and reentry fluid mechanics, heat transfer and flight dynamics; chemical and electric propulsion; spacecraft structural mechanics, spacecraft survivability and vulnerability assessment; contamination, thermal and structural control; high temperature thermomechanics, gas kinetics and radiation; lubrication and surface phenomena.

Space and Environment Technology Center: Magnetospheric, auroral and cosmic ray physics, wave-particle interactions, magnetospheric plasma waves; atmospheric and ionospheric physics, density and composition of the upper atmosphere, remote sensing using atmospheric radiation; solar physics, infrared astronomy, infrared signature analysis; effects of solar activity, magnetic storms and nuclear explosions on the earth's atmosphere, ionosphere and magnetosphere; effects of electromagnetic and particulate radiations on space systems; space instrumentation; propellant chemistry, chemical dynamics, environmental chemistry, trace detection; atmospheric chemical reactions, atmospheric optics, light scattering, state-specific chemical reactions and radiative signatures of missile plumes, and sensor out-of-field-of-view rejection.